CIRCULAR No. 155 JANUARY, 1931
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE ICE WELL FOR THE DAIRY FARM

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CONTENTS

INTRODUCTION

In the fall of 1928 an experimental ice well was constructed by the Bureau of Dairy Industry at the United States Dairy Experiment Station at Mandan, N. Dak., in cooperation with North Dakota State Agricultural College. Results were so successful during the following winter and summer that a preliminary report was issued to the press late in the fall of 1929. The second season's results are now available, and this circular is intended to furnish information to people who may be contemplating the construction of ice wells.

The northern Great Plains area of the United States is rather sparsely settled, and many farmers live a considerable distance from a cream station or shipping point. Natural ice is scarce, because of the lack of natural bodies of water such as rivers and lakes. These circumstances make it difficult for the farmers to have an ice supply during three or four months of the hottest weather in the summer. Consequently it is difficult for them to place their cream on the market in a condition that brings the highest price.

The ice-well " refrigerator " consists of a pit in the ground in which a solid cake of ice is formed by running small quantities of water into the pit daily in freezing weather. In the summer this pit of ice is closed up and used as a refrigerator or ice box for dairy and other food products. This method of farm refrigeration was first tried in Canada,[2] but as far as is known no investigational work has heretofore been carried out to test its adaptation to conditions in the northern part of the United States.

[1] J. R. Dice, head of the dairy department of North Dakota Agricultural College and Agricultural Experiment Station, acted in an advisory capacity.

[2] Storing ice, ice wells. (A publication not numbered or dated.) Dept. Agr. Prov. of Saskatchewan, Regina, Saskatchewan, Canada.

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CONSTRUCTION

A pit 8 feet square and 9½ feet deep was dug in a well-drained site about 10 feet from the milk house. (Fig. 1.) The soil was rather heavy. Several large stones were encountered and had to be removed. To insure that there would be good drainage from the bottom, a layer of coarse stone and gravel 1½ feet deep was put in the bottom of the pit. At each corner of the bottom of the pit post-

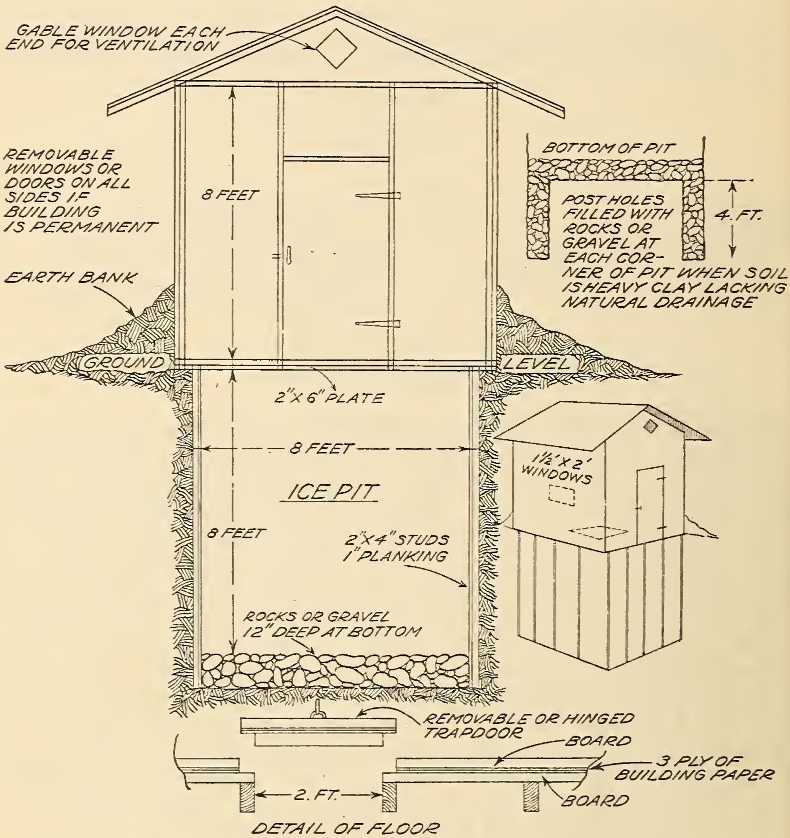

FIGURE 1.—Details of ice well and shelter building. There seems to be no reason why the ice well can not be of any practical size desired; the measurements given are only suggested. (Reproduced by courtesy Department of Agriculture, Province of Saskatchewan, Canada)

holes were dug, and these holes were filled with stone and gravel. These holes might not be necessary in other than extremely heavy soils, as the layer of stone and gravel might ordinarily be sufficient for good drainage. In light gravelly soils the layer of coarse stone and gravel in the bottom may not be needed.

The sides of the pit were then lined with cheap, rough lumber; 2 by 4 inch studs were placed upright 2 feet apart against the dirt sides, and rough 1-inch boards were nailed to these. This construc-

tion gives a 4-inch air space, if the dirt walls do not cave in. This air space is good insulation against the soil heat. The lumber was not treated in any way, and after two seasons' use there are no signs of rotting.

A small, inexpensive house was built over the pit. (Fig. 2.) Hinged, board windows were made in three sides of the house to insure good draft. These are dropped down and left open during freezing weather when ice is being frozen. In the summer they are kept tightly closed. A door was built in the front side of the house,

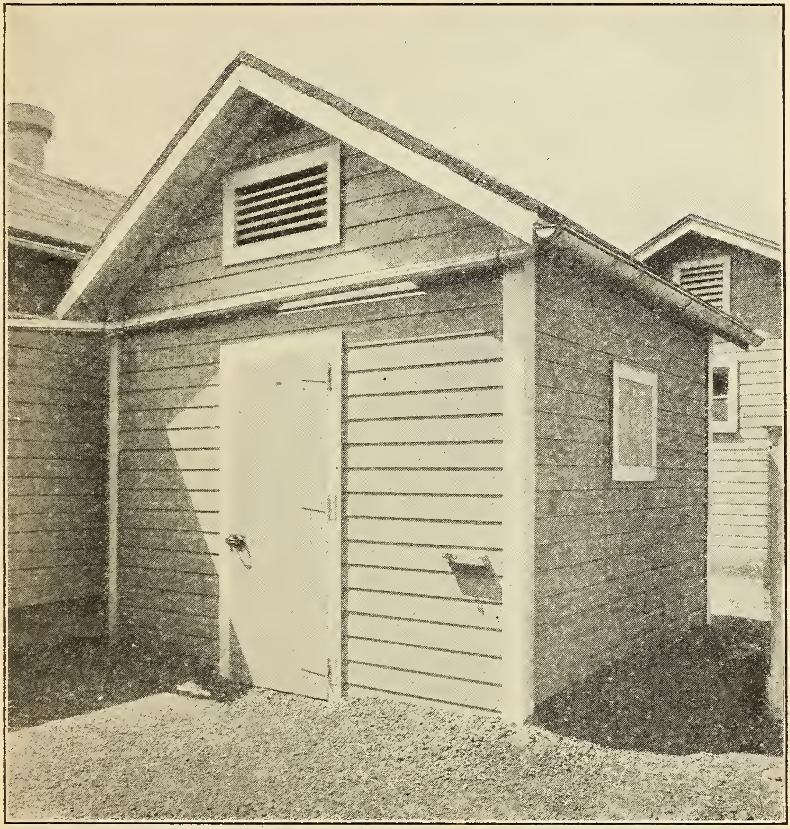

Figure 2.—The house over the ice well at Mandan. This picture was taken in the summer. The windows and doors are kept tightly closed as much of the time as possible in the summer, but open in the winter when the ice block is being frozen

which is also kept open in the winter and closed in the summer. A small gable-window ventilator was provided in each end near the roof.

The floor was built in sections so that the entire floor can be removed during the freezing period. The floor is of double thickness, with three thicknesses of building paper between the boards. Care was taken to have the sections fit closely in order that the pit might be closed tightly in summer.

A tightly fitting trapdoor was constructed in the central section of the floor. Through this door a wooden rack for the cream and milk cans is lowered and raised by means of rope and pulley, the pulley being fastened to a rafter above. (Figs. 3 and 4.) After the rack has been lowered to the ice block the trapdoor is closed tightly.

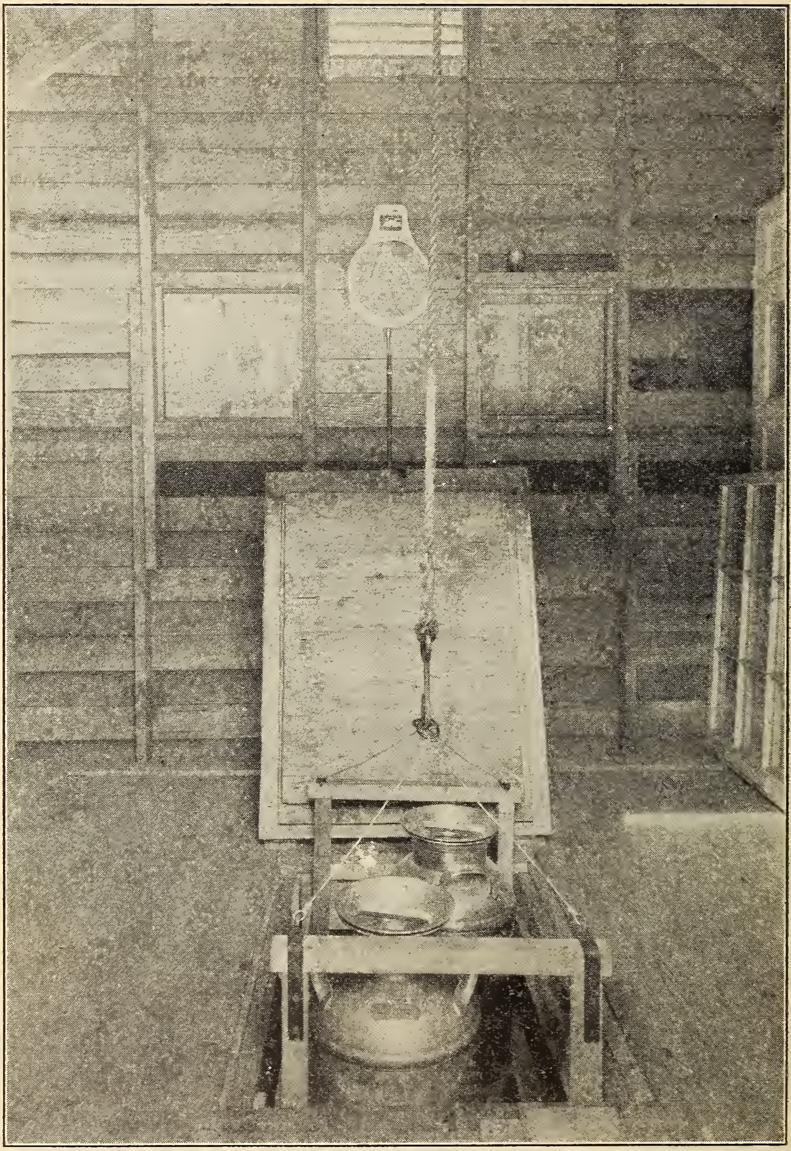

FIGURE 3.—Interior of ice-well house. Trapdoor in floor is open, and milk cans, on rack, are being lowered to the block of ice in the well below. The dial on the wall is that of the recording thermometer which makes a record of the temperature in the well. The bulb of the thermometer is in the pit below

OBSERVATIONS IN 1929

Early in January, 1929, the door and windows of the house were opened and the floor removed. Water was sprinkled on the gravel in the bottom of the pit at frequent intervals during the day. This was continued for five days. At the end of this time a 1½-inch layer of ice had been established on the bottom of the pit. Considerable

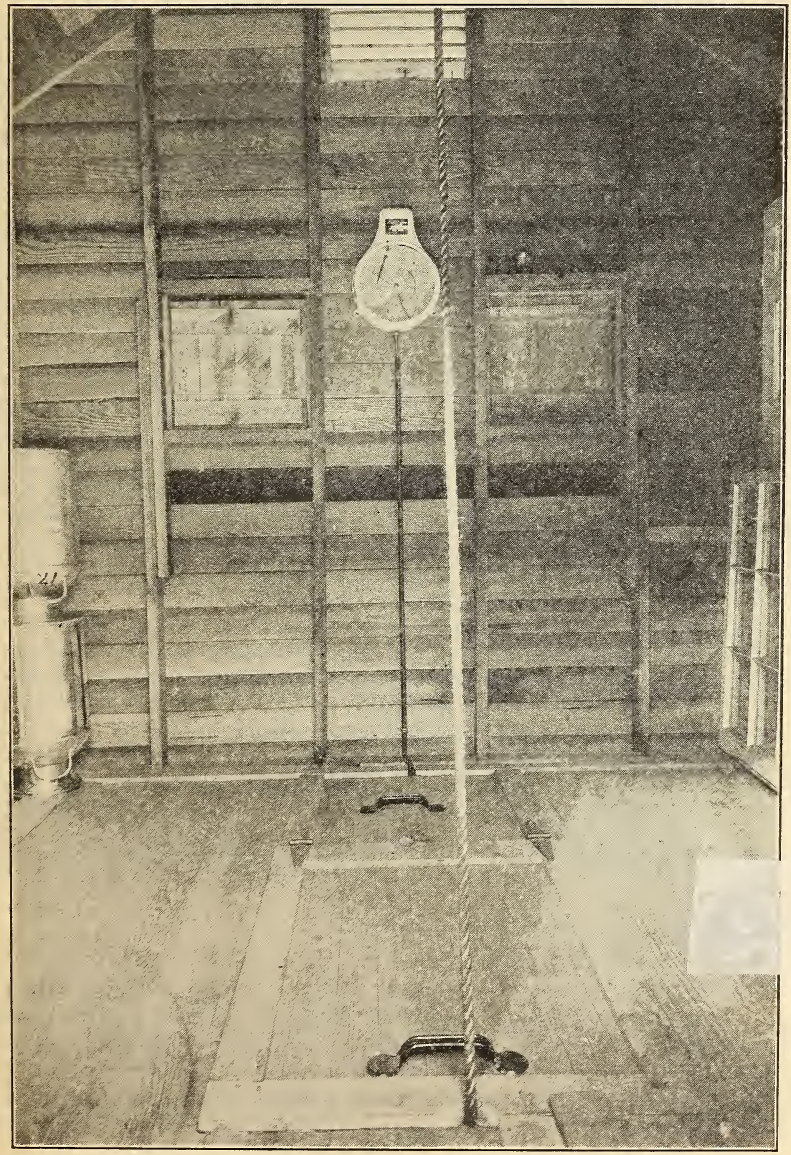

FIGURE 4.—Interior of the ice-well house, showing the trapdoor closed

difficulty was experienced in getting this foundation layer of ice formed because the water would drain away before it would freeze. This problem was solved, however, by throwing a few shovelfuls of snow into the pit and making a slush with water. After the first layer of ice was formed several bucketfuls of water were thrown in and allowed to freeze thoroughly before more water was added. The amount of water that was added depended upon the outside temperature. On extremely cold days as much as 120 gallons of water was added. This amount of water was sufficient to make a 3-inch layer of ice. By the end of February a solid block of ice 8 feet square and 6½ feet deep, measuring 416 cubic feet, had formed. Freezing was stopped when the block was 6½ feet deep, so that there would be room enough for a cream can between the top of the ice block and the floor of the house. The floor was then replaced and the door and windows tightly closed.

The cake was frozen in approximately two months, January and February. Some of the days during this period were too warm for satisfactory freezing. Table 1 gives the record of temperatures that prevailed during the period of this experimental work. In January, 1929, the mean temperature was minus 4.7° F., with a high of 39° and a low of minus 33°. In February, 1929, the mean was 2.5°, with a high of 33° and a low of minus 41°. There were only three days in January and February when the highest temperature was above freezing, and there were only 15 days during these two months when the lowest temperatures did not go below zero. It is readily seen that for this region the weather was sufficiently cold and the low-temperature periods were long enough to insure sufficient freezing.

TABLE 1.—*Monthly temperatures at Mandan, N. Dak., for months covered by ice-well experiments*

Year and month	Mean	Highest	Lowest	Mean for State	Year and month	Mean	Highest	Lowest	Mean for State
1929	°F.	°F.	°F.	°F.	1930	°F.	°F.	°F.	°F.
January	−4.7	39	−33	−4.8	January	−1.6	32	−31	−1.9
February	2.5	33	−41	2.8	February [1]	21.4	55	−15	21.7
May	50.4	81	20	49.1	May	50.8	87	26	50.8
June	62.3	91	35	61.4	June	64.2	88	42	63.3
July	73.2	108	46	70.6	July	74.4	102	47	72.3
August	70.6	101	36	68.5	August	70.6	99	45	70.4
September	52.4	103	25	52.7	September [2]	57.7	88	25	56.2
December	12.6	44	−25	12.5					

[1] One of the warmest Februarys in the history of the State.
[2] For Bismarck, 10 miles fom Mandan.

In 1929 the pit was opened and the use of the well for storing cream and other products begun on May 25. The ice lasted until September 28, a period of 126 days, or slightly more than four months. During this time fresh milk and cream were placed in the pit each day. Several hundred people visited the station in the course of the summer and were interested in seeing the ice well.

Hardly a day passed but that the well was opened at least once to show it to visitors, and on some days it was opened five or six times. Undoubtedly this frequent opening of the well caused the ice to melt faster than it would have otherwise.

The mean temperatures for May, June, July, August, and September, 1929, were 50.4° F., 62.3°, 73.2°, 70.6°, and 52.4°, respectively. (Table 1.) The highest temperature of the summer was 108°F., on July 26. On 27 days in June, July, and August the temperature reached 90° or higher.

RATE AND NATURE OF MELTING

Measurements were taken and notes made on the rate and nature of melting throughout the summer. In the 98-day period from May 25 to August 31 the top of the ice melted down a distance of 56 inches, or an average of 0.57 inch per 24 hours. The daily rate of melting from the top varied from 0.33 to 1.25 inches. Up to July 12 the melting was comparatively slow, but after that it was more rapid. The most rapid rate of melting (1.25 inches per day) was during the week of July 22, when the warmest weather of the summer occurred. The average rate of melting was 3.3 cubic feet of ice per day for the 126-day period from May 25 to September 28.

The rate of melting away from the walls of the well was practically the same on all sides, but there was a tendency for the north side to melt a little more rapidly than the others. A platform scale with a pit was located about 3 feet from the north side of the house, and that probably was responsible for the more rapid melting on that side. On August 31 the ice had melted a distance of 14 inches from the east, south, and west walls, and 15 inches from the north wall. The average rate of melting from each wall was 0.14 inch per day.

The first ice that melted was that along the side walls. For a short time this melting caused a slight depression along each side of the ice cake, in which a small quantity of water collected. This water was removed, and no more water collected on the block.

It was rather surprising to note that the ice directly under where the rack rested, melted somewhat slower than the rest of the cake resulting in a cone-shaped formation of ice on the top of the cake, where the rack rested. This formation was about 3 inches higher than the rest of the block. On July 23 this cone was leveled off to the level of the surrounding surface, and it did not form again.

TEMPERATURES IN THE PIT

Temperatures in the well were automatically recorded by a self-recording thermometer. The recording dial of this thermometer is seen in both Figures 3 and 4, attached to the rear end wall of the house. The bulb was placed at three different heights above the ice block—1 inch, 6 inches, and 12 inches—and temperatures were recorded for several weeks at each height. (Fig. 5.)

Table 2 shows the variation in temperature at the different heights. At 1 inch above the ice block the temperature varied from 38° to 42° F., with an average of 39°. At 6 inches above the ice the temperature was decidedly higher, the range being from 44° to 50°. At 12 inches the readings were about the same as at 6 inches. None of the temperatures recorded were higher than 50°.

FIGURE 5.—Down in the ice well, showing the top of the block of ice, with cans of cream setting directly on the ice, and with the bulb of the recording thermometer resting on a block of wood 6 inches above the ice. The thermometer tube is flexible, allowing the bulb to be placed in any position in the well

TABLE 2.—*Temperatures at distances of 1, 6, and 12 inches above the ice block for two summers*

Height of thermometer bulb above ice block (inches)	Summer of 1929			Summer of 1930		
	Highest	Lowest	Average	Highest	Lowest	Average
	°F.	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*
1	42	38	39	36	32	36
6	50	44	48	44	40	42
12	50	46	49	46	40	44

COOLING CREAM

The experimental work in cooling cream in the 1929 season was done with small quantities, about 15 pounds in each lot. All of the cream was precooled with cold water before it was lowerd into the ice well. With greater quantities of cream the results might have been somewhat different. The cream was precooled by putting the cream can in a container, through which the cooling water was circulated. The temperature of the cooling water averaged 52° F. The temperatures of the cream as it came direct from the separator at 7

a. m. averaged 80°. By 8.30 a. m. the cream had been cooled to a temperature of 56.3°. At this time it was placed in the rack on the ice block. The bottom of the can was approximately 1 inch above the ice. At 9.30 a. m., or at the end of an hour, the temperature of the cream was 52°; at the end of 3 hours it was 48°; in 4 hours it had dropped to 46°; and at 4.30 p. m., or in 8 hours, it had been cooled to 42°. The above data are the average data for 20 samples. The cream was thoroughly stirred before temperatures were taken.

Other lots of cream were precooled, and the cans were set directly on the ice block. The average temperature of the cream when set on the ice block was 56.3° F. After 2 hours the temperature had dropped to 42°; in 4 hours the temperature was 37°; and in 6 hours it was 34°, which remained constant.

Setting the cans directly on the ice block cooled the cream much more rapidly and to a lower temperature than was the case when the cans were set on the rack an inch above the ice.

The cream of June 10, 11, and 12 was held on the rack 1 inch above the ice until June 18. Each lot was cooled and then put in the can on the following day. The full can was sold on June 18, and the creamery reported as follows: "Cream in good condition; clean, sweet, and has no foreign flavor; acidity 0.25 per cent."

A can of cream was placed in the well in direct contact with the ice on July 1. On July 15 (14 days later) it was sold. It was graded as sweet but had a noticeable metallic flavor. The acidity was 0.24 per cent. This experiment was made to show how long cream could be held in the ice well. The practice of holding cream for long periods, however, is not advocated.

In 1929 all of the cream was precooled with water before it was put in the ice well. In the 1930 season some of the cream, and also milk, was not precooled. The data for 1930 are given on pages 10 and 11.

Butter was successfully stored in the ice well.

Throughout the summer of 1929 no objectionable odors were detected in the well or in anything stored. Molds did not develop on the can rack or in the lower part of the pit. In August a slight mold was noticed on the two upper boards of the well lining, that is, to a depth of approximately 20 inches from the floor of the house.

OBSERVATIONS IN 1929–30

The freezing of the block of ice was accomplished in much the same way in 1929-30 as in the previous winter. Freezing started early in December, however, about a month earlier than in the preceding winter. By February 3 the ice had formed to within 20 inches of the floor.

At this time a box the same size as the trapdoor and rack was placed on the ice directly under the trapdoor. Water was added to the surface of the ice surrounding this box until ice was formed up to the sills of the floor. When the box was lifted out of the ice block there was a depression in the middle of the ice 20 inches deep into which the rack could be lowered. By this method a larger block of ice, the total volume of which was approximately 505 cubic feet, was formed. However, it is doubtful whether the larger size of the block formed in this way was of any practical advantage.

The depression filled with water after melting started, and that apparently caused more rapid melting than occurred the year before. The depression which was left by removing the box disappeared about the eighty-fifth day.

The temperatures this winter were considerably higher than those the previous winter. (Table 1.) The mean temperatures for December, 1929, and January, 1930, were 12.6° and −1.6° F., respectively. However, no difficulty whatever was experienced in getting the ice frozen.

The ice pit was opened and milk and cream storage begun on May 4, about 20 days earlier than the previous summer. The ice lasted until September 28, a period of 147 days. The rate of melting from the top was greater, averaging 0.67 inch per day, as compared with 0.57 inch per day the previous summer. This is accounted for by the fact that most of the products were not precooled in 1930, which caused greater consumption of ice than in 1929. The nature of the melting from the sides was practically the same both years. The ice melted at the rate of 3.4 cubic feet per day.

The temperatures, taken at heights of 1 inch, 6 inches, and 12 inches above the ice block, ranged from 4° to 6° F. lower in the summer of 1930 than in the summer of 1929. (Table 2.) The more rapid melting of the larger ice block in 1930 may have been responsible for this lower range of temperature.

The temperatures in June, July, August, and September, 1930, are given in Table 1. The mean temperatures for the respective months were nearly the same for both years.

MILK AND CREAM HOLDING EXPERIMENTS IN 1930

Sixteen trials were made with small amounts (7 to 8 pounds) of cream precooled with water to a temperature of 60.5° F. and then placed in cans directly on the ice block. Average results of the 16 trials were as follows: In 1 hour the temperature dropped to 48.7°; in 3 hours to 40°; in 4 hours to 37°; and in 7½ hours to 34.4°.

Twenty trials were made with small amounts of cream not precooled and set directly on the ice at an average temperature of 85.4° F. In 1 hour the cream had cooled to 61.6°; in 2 hours to 49.3°; in 4 hours to 41.7°; in 5 hours to 38.5°; and in 9 hours to 35.3°.

Although these results indicated that apparently there was little to be gained by precooling, it is believed that the practice of precooling would pay, especially with large amounts of cream, as the precooled cream used less ice. If greater quantities of cream had been used the temperatures might have been somewhat different from those that were recorded.

Three trials were made with full 10-gallon cans of milk not precooled. These cans were set directly on the ice. The average temperature of the milk was 91.3° F. when the cans were set on the ice block. In 2 hours the temperature was 79.6°; in 3 hours, 72.5°; in 5 hours, 60.3°; in 6 hours, 57.6°; and in 9½ hours the average temperature of the milk was 48°. There was but little variation in the three samples. Each can of warm milk settled into the ice a distance of 3 or 4 inches. The milk was stirred only when temperatures were taken.

Eight full cans of milk were precooled to a temperature of 64.7° F. and set directly on the ice block at 8.30 a. m. In 1 hour the average temperature was 59.6°; in 3 hours, 53.2°; in 4 hours, 49.7°; and in 7½ hours, 44.7°.

In this case precooling was advantageous, not only because of the rapidity of lowering the temperature of the milk, but also because less ice was used. With full cans of milk, precooling was necessary to lower the temperature of the milk in a short time to a point where bacteria multiply slowly.

A can containing 38 pounds of precooled cream collected on August 4, 5, and 6 was held directly on the ice block and sold on August 19 at an average age of 14 days. When the cream was sold the acidity was 0.22 per cent. Another can containing 36 pounds of cream collected on August 9, 10 and 11 was not precooled and was held on the ice block until August 24. The acidity of this when sold was 0.22 per cent. Both lots of cream were stirred twice daily throughout the storage periods. Apparently the precooling had little effect on the acidity of the cream. However, it is to be borne in mind that the amount of cream put into the can daily on each of the three days was only 12 to 13 pounds.

OBSERVATIONS ON A CONCRETE ICE WELL

The success which has attended these experiments with this ice well at Mandan, N. Dak., led the Bureau of Dairy Industry to conduct experiments with a different type of ice well at the United States Dairy Experiment Station at Ardmore, S. Dak.[3] The well at Ardmore was made circular in form instead of square, and was lined with a concrete wall varying from 4 to 7 inches in thickness. The floor and house above the pit are similar to those at Mandan. The Ardmore well is located in a corner formed by the north wall of a covered alleyway and the west wall of the milk room. On the west it is sheltered by a barn.

Freezing was started on December 6, 1929. Little difficulty was experienced in getting the floor coated with ice, but the weather was intermittently warm and cold in December, and very little ice formed in that month.

In January the temperature was zero or below on 27 days of the month, and freezing in the well was rapid. On an average, 50 gallons of water was poured into the well daily. This amount of water formed approximately 1.8 inches of ice. In February and March the weather was moderate and only a little ice formed in these months. At the end of the freezing period for the well, March 2, there was a solid cake of ice 63 inches deep, which had a volume of approximately 232 cubic feet.

By April 1 the ice block had melted to a depth of 58 inches, and by May 1 it was only 39 inches deep and had melted away from the circular wall about 7 inches. By June 15 the ice had completely melted.

The reason for such rapid melting so early in the season is not definitely known, but the assumption is that the concrete, which was

[3] These observations were made by Ray H. Smith, in charge of the dairy work at the Ardmore station.

not insulated, conducted heat from the surrounding ground into the ice chamber. Another reason may be the close proximity of the well to a water main and sewer line. Also, on account of the fact that the well is in a somewhat sheltered location, all of the surrounding soil may not have frozen. It is believed that the noninsulated concrete wall was the chief factor in the rapid melting. In further experimental work the concrete pit will be lined with lumber as an insulating material.

Many suggestions have been made concerning the form of construction, material to use, and the method of operation of an ice well. Some of these are: (1) Use galvanized iron as a lining; (2) treat the lumber with creosote or other preservative to prevent rotting; (3) pack straw or sawdust between wooden lining and outside soil to provide better insulation; (4) install water coils in bottom of pit and freeze ice around them so as to provide a supply of cold water for cooling milk in the summer; (5) fill the well with snow instead of ice; and (6), make the pit deeper to provide a larger supply of ice.

Some of these suggestions may have considerable merit and will be considered in future experimental work.

CONCLUSIONS

Ice wells constructed according to the method employed and material used at Mandan, N. Dak., are practical and successful under the temperature conditions prevailing in that section. It is thought that such ice wells are adapted to any locality where winter freezing temperatures are sufficiently low and extend over long enough periods to freeze enough ice in the pit.

By being careful to conserve the ice, sufficient ice can be made to last over a period of approximately four months during the summer for ordinary dairy-farm use.

In the two experiments described, lumber has been the best material for lining the well. Noninsulated concrete was not suitable as used.

Milk, cream, and butter can be successfully stored in the ice well for reasonable periods of time. No offensive odors result when care and cleanliness are practiced.

For small lots of cream, precooling with cold running water is not necessary, but it is desirable. For large lots of cream it is advisable to precool with cold water, to conserve the ice and to bring about more rapid cooling. It is advisable to precool whole milk before storing it in the ice well.

The ice well can be made at low cost. The lumber used in the well can be cheap and rough. The house over the pit should be tight and durable, but it need not be expensive.

IMPORTANT POINTS IN CONSTRUCTION AND OPERATION

(1) Locate the well close to a clean water supply and to the milk house; (2) provide good drainage, both inside and out; (3) be sure that the house floor which covers the pit is tight and well insulated; (4) keep the house tightly closed and open it only when necessary in summer; and (5), if milk or cream is spilled on the ice or in the pit clean it up immediately to avoid objectionable odors.

U. S. GOVERNMENT PRINTING OFFICE: 1931